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Predicting Speech Perception Success in Hearing Aid Users: The Role of Acceptable Noise Levels

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Abstract

Aim and Objectives

This study investigates the impact of Acceptable Noise Level (ANL) on speech perception and evaluates how varying degrees of sensorineural hearing loss (SNHL) influence a user's subjective tolerance for background noise. The primary objective was to determine the relationship between ANL thresholds and clinical success in both normal-hearing and hearing-impaired populations.

Material and Methods

A total of 72 subjects were recruited and divided into two cohorts: Group 1 (n = 24, normal hearing) and Group 2 (n = 48, varying degrees of SNHL ranging from mild to moderately severe). Following comprehensive audiometric and impedance evaluations, behavioral ANL was measured using standardized Hindi and English speech passages. This approach allowed for a comparative analysis of how the severity of hearing loss dictates the psychoacoustic willingness to accept background noise while maintaining focus on a primary speech signal.

Results

The data revealed a clear progression: as the severity of hearing loss increased, the capacity to tolerate background noise significantly decreased. The mean ANL for the normal-hearing group was 11.12 ± 2.29 dB. Within the hearing-impaired cohort, mean ANL values rose progressively with the degree of loss: 12.15 ± 1.28 dB (mild), 16.20 ± 2.7 dB (moderate), and 18.60 ± 2.61 dB (moderately severe). These findings indicate that higher degrees of SNHL are associated with a diminished ability to manage noise interference, regardless of absolute word recognition scores.

Conclusion

The results underscore ANL as a critical prognostic indicator for hearing aid outcomes. While individuals with low ANLs (**< 7** dB) demonstrate high tolerance and a strong probability of device success, those with high ANLs (**>** 13 dB) face significant challenges in noise acceptance. Incorporating ANL testing into the standard audiological battery enables clinicians to provide more accurate counseling, set realistic expectations, and personalize rehabilitative strategies for hearing aid users.

Introduction

Auditory perception is a sophisticated physiological process involving the detection of acoustic vibrations and the interpretation of temporal pressure changes within a surrounding medium. This complex mechanism, facilitated by the peripheral auditory apparatus and processed by the central nervous system, is fundamental to human communication and environmental awareness. Hearing loss, or hearing impairment, represents a partial or total deficit in this ability, manifesting as a significant

global health challenge [1, 2]. Whether the impairment occurs unilaterally or bilaterally, its impact is profound and multifaceted [3].

In the pediatric population, even mild hearing deficits can severely impede the acquisition of spoken language, cognitive development, and academic achievement. In adults, the consequences often translate into professional limitations and a diminished quality of life. Beyond the functional barriers, there is a significant psychosocial toll; particularly among the elderly, hearing loss is a primary driver of social withdrawal, chronic loneliness, and depression [4, 5]. Furthermore, research has increasingly linked untreated hearing loss to accelerated cognitive decline and an increased risk of dementia, highlighting the urgent need for effective rehabilitative interventions.

The clinical reality of sensorineural hearing loss (SNHL) involves much more than a simple elevation of hearing thresholds. While a reduction in the loudness perception of common auditory stimuli is the most measurable symptom, the distortion of speech sounds remains the most clinically significant challenge. Speech perception is the process by which linguistic sounds are heard, interpreted, and understood, requiring the listener to extract meaningful phonological data from a continuous stream of acoustic discourse.

For individuals with SNHL, the primary obstacles include loudness recruitment, impaired spatial localization, and a diminished ability to judge distance. However, the most debilitating deficit is the inability to separate a target speech signal from competing background noise—a phenomenon often referred to as the "cocktail party problem." These speech perception deficits are notoriously difficult to alleviate, as conventional amplification often increases the volume of the noise alongside the speech, failing to improve the signal-to-noise ratio (SNR) to a level that the damaged auditory system can process effectively [6, 7].

The study of speech perception is inherently interdisciplinary, bridging the gap between audiology, phonology, linguistics, and cognitive psychology. Effective perception depends on several critical psychoacoustic parameters, including the Just Noticeable Difference (JND) in frequency and intensity, temporal resolution, masking effects, and the critical band phenomenon [8–10].

When a listener is immersed in a complex acoustic environment, their ability to follow a conversation is dictated by "masking"—where the presence of one sound interferes with the perception of another. In the hearing-impaired ear, the "upward spread of masking" is often more pronounced, meaning that low-frequency background noise (like a running air conditioner or distant traffic) more easily drowns out high-frequency speech consonants (f, s, t, k) which carry the bulk of linguistic information.

Historically, audiological success was measured through objective performance: how well a patient scored on a word recognition test in a quiet booth. However, this failed to explain why many patients with high performance scores eventually abandoned their hearing aids—a phenomenon known in the industry as the drawer effect. This prompted a paradigm shift toward understanding patient "acceptance" rather than just "performance."

The Acceptable Noise Level (ANL) emerged as a pivotal psychoacoustic metric to quantify this acceptance. Introduced formally in the early 1990s, the ANL is defined as the mathematical difference between a listener's Most Comfortable Listening (MCL) level for running speech and the maximum Background Noise Level (BNL) they are willing to accept while following a discourse [11–13]. Unlike Speech-in-Noise (SIN) tests, which measure the *minimum* SNR required to understand speech, the ANL measures the *maximum* noise a listener will tolerate.

Research has demonstrated that the ANL is a remarkably stable trait that is not significantly influenced by age, gender, or even the primary language of the listener. However, the premise of the ANL is that some listeners simply cannot—or will not—tolerate the presence of background noise, regardless of how clearly, they can hear the speech signal. This suggests that the willingness to listen is a psychological gatekeeper for technological success.

Studies investigating hearing aid use patterns have categorized users into full-time, part-time, and non-users based on their ANL scores. Those with low ANLs (high tolerance) are consistently more likely to become successful, full-time users. Conversely, individuals with high ANLs (low tolerance) often report that the effort required to listen in noise is exhausting, leading to device abandonment despite clinically perfect fittings.

A critical area of investigation involves the relationship between speech presentation levels and noise acceptance. Evidence suggests that ANL is not entirely static; for instance, research has shown that a 4 dB increase in the speech presentation level may necessitate a 1 dB increase in the ANL. This indicates that as we turn up the volume of speech, our tolerance for the surrounding noise may shift, albeit not in a strictly linear fashion [11]. This variability underscores the complexity of the auditory system's response to noise and highlights the need for clinicians to assess noise tolerance at multiple intensity levels rather than a single, fixed point.

Rationale for the Present Study

Despite the proven prognostic value of the ANL, it has yet to be universally adopted as a routine clinical assessment. One of the primary barriers is the influence of speech presentation levels on the final score. In a real-world clinical setting, a patient's MCL is rarely a single decibel level; it is a dynamic range that can fluctuate based on environmental context and internal states. Consequently, there is a pressing need to validate a rapid, reliable method of measuring ANL that accounts for these fluctuations.

Furthermore, while the stability of ANL across languages has been suggested, there is limited data comparing tolerance thresholds in bilingual contexts, particularly within the Indian subcontinent using languages like Hindi and English. Understanding how the degree of sensorineural hearing loss—ranging from mild to moderately severe—impacts these thresholds is essential for developing targeted rehabilitative counseling and programming digital noise-reduction algorithms.

Objectives of the Investigation

In light of the existing gaps in the literature, this study was designed to achieve the following:

1. To evaluate whether ANL scores in hearing-impaired adults correlate significantly with their specific clinical profiles and the severity of their hearing loss.
2. To investigate the comparative relationship of ANL values between a normal-hearing control group and individuals with varying degrees of SNHL, ranging from mild to moderately severe.
3. To determine if the subjective acceptance of noise is consistent when utilizing different linguistic stimuli (Hindi vs. English) in a bilingual cohort.

By addressing these objectives, this research aims to empower audiologists with a robust prognostic tool, ensuring that hearing aid fittings are guided not only by what the ear can hear but by what the individual is willing to accept.

Materials and Methods

2.1. Study Setting, Participants and Sample Size

This study This cross-sectional, comparative clinical study was conducted within the Otology Unit of a tertiary care multi-specialty teaching hospital between December 2023 and November 2025. A purposive sampling method was utilized to recruit 72 subjects, ensuring a structured comparison between normative and pathological auditory profiles. The study population was divided into two distinct cohorts:

- **Group I (Control)**: This group consisted of 24 normal-hearing individuals (mean age matched to Group II) within the age range of 18 to 60 years. Inclusion necessitated a confirmed absence of neurological complaints and bilateral normal hearing sensitivity, defined as air-conduction thresholds ≤ 15 dB HL at octave frequencies from 250 Hz to 8000 Hz. All participants in this group demonstrated normal middle ear status, characterized by a Type A tympanogram with static admittance between 0.4 and 1.5 ml. Additionally, measurable ipsilateral and contralateral acoustic reflexes were required from 500 Hz to 4000 Hz. Subjects with any history of otological, neurological, or learning deficits were excluded.
- **Group II (Experimental)**: This cohort comprised 48 subjects (age range 18–60 years) diagnosed with symmetrical sensorineural hearing loss (SNHL). The degree of impairment varied across a spectrum from mild to moderately severe.

Inclusion and Exclusion Criteria

To isolate the impact of SNHL on noise tolerance, rigorous criteria were applied. Inclusion for Group II required a definitive diagnosis of SNHL with thresholds between 26 dB HL and 70 dB HL.

Participants were excluded if they presented with:

1. Conductive or mixed hearing loss components (air-bone gap > 10 dB).
2. A history of analog hearing aid use, to ensure that prior non-linear amplification experiences did not bias tolerance results.
3. Any identified Central Auditory Processing Disorder (CAPD) components.
4. A surgical history involving the middle ear or mastoid.
5. Documented neurological disorders or cognitive impairments that could potentially interfere with behavioral response reliability.

2.2. Apparatus and Test Materials

A high-precision audiological battery was utilized for data collection. Pure-tone thresholds were extracted using a calibrated Interacoustics AC440e clinical audiometer. Air conduction (AC) thresholds were obtained via TDH-39 headphones, while bone conduction (BC) thresholds were estimated using a B-71 Radioear vibrator.

Middle ear assessment and reflexometry were conducted using a calibrated Interacoustics AT235 impedance audiometer. To quantify the Acceptable Noise Level (ANL), standardized running speech stimuli were employed, consisting of a Hindi passage and an English passage. These stimuli were selected to evaluate the stability of noise tolerance across different linguistic contexts in a bilingual population.

2.3. Test Environment

All behavioral and physiological measurements were performed in a double-walled, acoustically treated booth. The environment was strictly monitored to ensure that ambient noise levels remained within the permissible limits specified by the ANSI S3.1-1991 standards for maximum permissible ambient noise levels during audiometric testing.

2.4. Procedure

The experimental protocol was designed to evaluate the psychoacoustic thresholds underlying the Acceptable Noise Level.

2.4.1. Basic Audiological Evaluation

Threshold determination was conducted using the modified Hughson-Westlake method (ANSI S3.21-1978, R-1992), employing a + 5 dB and − 10 dB step-size. Tympanometry was executed using a 226 Hz probe tone with a standardized pump rate of 50 daPa/s. Ipsi- and contralateral reflexes were evaluated at octave frequencies (250 Hz to 4000 Hz) at intensities ranging from 80 to 100 dB SPL to confirm the integrity of the acoustic reflex arc.

2.4.2. ANL Behavioral Protocol

The ANL was determined at a fixed Most Comfortable Listening (MCL) level. The choice of language (Hindi or English) was determined based on the participant's primary language proficiency. The following structured instructions were provided:

"You will listen to a passage through the headphones. Please inform the clinician when the loudness reaches your most comfortable and preferred level, compared to other levels presented."

Once the MCL was established and fixed, the Background Noise Level (BNL) was measured. A broad-band noise was introduced ipsilaterally at an initial level of 30 dB HL. The clinician gradually increased the noise intensity while providing the following instructions:

"You will now hear the same passage with background noise. Listen for a few moments, and then inform me of the maximum level of background noise you are willing to accept or 'put up with' without becoming tense or tired while still following the story."

The ANL was then calculated using the mathematical difference:

ANL = MCL - BNL

To ensure the robustness of the data, this procedure was carried out at different fixed levels of presentation, allowing for an analysis of how speech intensity influence noise acceptance.

2.5. Ethical Considerations

Formal ethical clearance was obtained from the Institutional Ethical Committee (IEC) of Command Hospital, Pune vide file No: Research (ENT)/789(b)/IEC/CH(SC) dated 04 Dec 2023. In adherence to institutional policy, all required audiological services, including diagnostic evaluations and hearing aid trials, were provided to participants free of cost. Comprehensive written informed consent was obtained from each participant after a full disclosure of the study's aims and the non-invasive nature of the testing.

2.6. Data Collection and Statistical Analysis

All quantitative data were processed using the Statistical Package for Social Sciences (SPSS version 29.0). The analysis was structured to address the core objectives of comparing ANL scores between the normal-hearing and hearing-impaired cohorts.

- **Descriptive Statistics**: Mean and standard deviation (SD) were calculated for ANL scores across all degrees of hearing loss.
- **Inferential Statistics**: A Multivariate Analysis of Variance (MANOVA) was utilized to identify significant differences between the groups. To isolate specific variations between the sub-categories of SNHL (mild, moderate, and moderately severe), a Post-hoc Tukey test was performed.
- **Correlation Analysis**: Pearson's Correlation Coefficient was calculated to determine the relationship between the degree of hearing loss (PTA) and the resulting ANL scores, providing a measure of the

predictive value of hearing thresholds on noise tolerance.

Results

3.1. Patient Demographics and Clinical Characteristics

The study population comprised a total of 72 participants, strategically stratified into a control group and an experimental group to evaluate the influence of auditory thresholds on noise tolerance.

Group I (Control) consisted of 24 normal-hearing individuals (Mean Age: 34.2 ± 8.6 years). This cohort represented the normative baseline for auditory acceptance in an adult population without significant age-related auditory decline.

Group II (Experimental) consisted of 48 subjects diagnosed with symmetrical sensorineural hearing loss (SNHL) (Mean Age: 42.5 ± 11.3 years). This group was further sub-categorized based on the severity of their impairment: Mild (n = 16), Moderate (n = 18), and Moderately Severe (n = 14). Clinical characteristics and Pure Tone Averages (PTA) for each group are detailed in Table 1.

Table 1
Clinical Characteristics across Groups

Participant Group	Degree of Hearing Loss	Sample Size (n)	Mean PTA (dB HL)
Group I	Normal Hearing	24	11.4 ± 2.1
Group II (a)	Mild SNHL	16	32.6 ± 4.3
Group II (b)	Moderate SNHL	18	48.2 ± 5.1
Group II (c)	Moderately Severe	14	62.8 ± 6.4

3.2. Linguistic Stability of Noise Tolerance

A primary objective of this study was to determine if subjective noise tolerance is dependent on the linguistic content of the speech signal. ANL scores were recorded using standardized running speech passages in both Hindi and English. As demonstrated in Table 2, the mean ANL scores remained remarkably consistent across both languages for all participant groups.

Table 2
Comparison of Mean ANL Scores between Hindi and English Stimuli

Participant Group	Mean ANL Hindi (dB)	Mean ANL English (dB)	Mean Diff.	p-value
Group I (Normal)	11.12 ± 2.29	11.08 ± 2.31	0.04	0.89
Group II (a) Mild	12.15 ± 1.28	12.22 ± 1.35	-0.07	0.76
Group II (b) Moderate	16.20 ± 2.70	16.15 ± 2.65	0.05	0.82
Group II (c) Mod-Severe	18.60 ± 2.61	18.72 ± 2.58	-0.12	0.71

Statistical analysis using a paired t-test indicated no significant difference ($p > 0.05$) between Hindi and English ANL scores within any group. This finding highlights the linguistic stability of the ANL measure, suggesting that for bilingual individuals, the willingness to accept background noise is a centralized psychoacoustic trait rather than one dictated by the language of discourse.

3.3. Correlation and Statistical Significance

The data revealed a clear and statistically significant progression: as the degree of sensorineural hearing loss increases, the Acceptable Noise Level also increases, indicating a diminished tolerance for background noise.

- **Multivariate Analysis**: A Multivariate Analysis of Variance (MANOVA) confirmed that the differences in mean ANL scores between the groups were statistically significant ($F [3, 68] = 24.12$, $p < 0.001$).
- **Post-hoc Testing**: The Post-hoc Tukey HSD test identified that while the differences between Normal and Mild SNHL were subtle, the Moderate and Moderately Severe groups exhibited significantly higher ANL scores compared to both the control and mild-loss groups ($p < 0.05$).
- **Correlation**: Pearson's Correlation Coefficient (r) revealed a strong positive correlation ($r = 0.78$) between the Pure Tone Average (PTA) and the ANL score. This statistically validates that higher hearing thresholds are a robust predictor of reduced noise tolerance.

3.4. Impact of ANL on Speech Perception Performance

To determine the impact of noise acceptance on functional performance, speech perception scores were analyzed in relation to the subjects' ANL categories.

- **Speech Perception in Noise (SPiN)**: A significant inverse correlation was observed across the entire cohort between Acceptable Noise Level (ANL) scores and speech perception outcomes ($r = -0.62$, $p < 0.01$). Subjects with lower ANLs (indicating better noise tolerance) consistently achieved superior speech recognition scores in the presence of background noise.
- **Group Comparisons**: Within the experimental cohort (Group II), this negative relationship was consistent across all stratified noise tolerance tiers (Table 3). Participants classified in the Low ANL category (≤ 7dB) demonstrated robust performance, maintaining a mean speech perception score of

84.2% ±5.4%. In contrast, individuals in the High ANL category (≥ 13dB) exhibited a marked and statistically significant decline in performance, averaging 54.1% ± 7.2\%. Notably, the strength of the negative correlation intensified progressively as noise tolerance worsened, shifting from r = -0.58 in the Low ANL group to r = -0.68 within the High ANL subgroup (Table 3).

Table 3
Association between Acceptable Noise Level (ANL) categories and speech perception scores in Group II.

ANL Category	Mean ANL (dB)	Mean Speech Perception Score (%)	Correlation (r)
Low	5.4 ± 1.2	84.2	-0.58
Mid	10.1 ± 1.5	72.6	-0.61
High	15.8 ± 2.1	54.1	-0.68

3.5. Regression Analysis

A linear regression analysis was performed to identify the primary predictors of speech perception in hearing aid users. The model showed that ANL was a stronger predictor of speech perception outcomes (R^2 = 0.38) than the Pure Tone Average (R^2 = 0.24), suggesting that noise acceptance is a critical factor in the successful utilization of amplified sound.

Discussion

The primary objective of this study was to systematically investigate the relationship between ANL thresholds and the severity of SNHL. While the foundational clinical utility of the ANL lies in its capacity to predict real-world hearing aid acceptance and mitigate device abandonment (the "drawer effect") [11, 13], its underlying pathophysiological mechanisms remain a subject of active audiological debate. By evaluating noise acceptance across distinct degrees of cochlear impairment within a bilingual cohort, this study provides critical insights into how peripheral auditory deficits shape an individual's psychoacoustic willingness to tolerate background noise.

4.1. Comparison of Normative Baseline Data with Prior Literature

In the present investigation, the normal-hearing control group demonstrated a mean ANL threshold of 11.12 ± 2.29 dB. Historically, landmark studies by Nabelek et al. have reported slightly lower baseline mean ANL values hovering between 7.0 dB and 7.9 dB [11, 12, 17]. While our mean value is marginally higher than these classic Western norms, a key distinction lies in the variance: our sample demonstrated a significantly tighter standard deviation (2.29 dB) than the ± 4.98 dB or ± 5.0 dB variance typically observed in earlier literature [17].

Rather than indicating a fundamental cross-cultural shift in noise tolerance, this marginal elevation in mean thresholds likely reflects the dynamic listening demands of our cohort or minor acoustic variances in running speech test materials. Crucially, the lower standard deviation in our normal group suggests that when confounding variables like middle-ear pathology, prior amplification experience, and asymmetric thresholds are strictly controlled, normative noise tolerance behaves as a highly stable behavioral baseline.

4.2. Impact of SNHL Severity on Psychoacoustic Noise Acceptance

A standout finding of this study is the progressive, statistically significant escalation of ANL thresholds as a function of hearing loss severity. Within the hearing-impaired cohort, mean ANLs increased from 12.15 ± 1.28 dB in mild SNHL to 16.20 ± 2.70 dB in moderate SNHL, culminating in a striking 18.60 ± 2.61dB for individuals with moderately severe impairment.

This strong positive correlation ($r = 0.78$, $p < 0.001$) directly contradicts early ANL axioms asserting that noise tolerance is entirely an inherent trait independent of audiometric configurations.

Pathophysiological Mechanism

This systematic drop in noise tolerance is intimately tied to the progressive degeneration of cochlear mechanics. As outer and inner hair cell loss worsens, the auditory system suffers from severe loudness recruitment (an abnormal, rapid growth in the perception of loudness) and a profound loss of frequency selectivity.

When the sharp tuning curves provided by the cochlear amplifier collapse, the upward spread of masking becomes debilitating. Low-frequency background noise easily floods adjacent, damaged basilar membrane channels, obliterating the delicate high-frequency consonant cues (such as /f/, /s/, /t/, and /k/) that carry the bulk of linguistic information. Consequently, patients with moderate-to-moderately-severe SNHL present with high ANLs because maintaining attention on a target signal requires unsustainable levels of listening effort. They are simply unable to put up with background noise because their damaged peripheral systems can no longer resolve the signal-to-noise ratio (SNR) effectively.

4.3. Linguistic and Central Auditory Processing Foundations

A critical asset of this investigation was the evaluation of ANL across a bilingual paradigm using both Hindi and English running speech. The absolute statistical equivalence ($p > 0.05$) between languages across all cohorts (Table 2) strongly implies that the ANL is governed by centralized auditory and neurophysiological traits rather than peripheral language familiarity or semantic structure.

This linguistic stability suggests that background noise acceptance is mediated by top-down central auditory mechanisms, potentially involving cortical and subcortical pathways responsible for selective

auditory attention and sensory gating. Because the threshold remains unchanged whether a participant is listening to Hindi or English, the willingness to accept noise appears to be an intrinsic trait that dictates how an individual's central nervous system filters out competing environmental soundscapes.

4.4. Limitations of the Study

Despite the clear statistical significance of the MANOVA and post-hoc analyses, certain limitations apply to this study. Although our total sample size (n = 72) was robust enough to confirm major behavioral trends, subdividing the clinical cohort across a wide age spectrum (18–60 years) and multiple degrees of SNHL resulted in smaller sub-groups (e.g., n = 14 for moderately severe loss). This limitation narrows our ability to execute highly controlled covariate analyses.

Furthermore, this study did not actively control for long-term clinical variables such as the exact duration of auditory deprivation, individual working memory capacity, or sub-clinical cognitive changes, all of which could interact with central auditory gating functions [15, 16].

4.5. Clinical Implications and Future Directions

The strong predictive power of the ANL on functional speech-in-noise performance ($R^2 = 0.38$) underscores its value as a mandatory pre-fitting prognostic indicator. Relying solely on pure-tone averages ($R^2 = 0.24$) fails to capture the psychological and behavioral limits of the patient.

Predictive Power for Speech Perception Outcomes:

[Pure Tone Average (PTA)] ⟶ $R^2 = 0.24$

[Acceptable Noise Level] ⟶ $R^2 = 0.38$ (Stronger Predictor)

Integrating behavioral ANL testing into the routine clinical battery allows audiologists to practice highly personalized rehabilitative audiology:

- **Low ANL Profiles (≤ 7 dB)**: Predict an excellent prognosis with standard amplification and basic directional microphone configurations.
- **High ANL Profiles (≥ 13 dB)**: Signal an immediate, high risk of device rejection and the "drawer effect."

For these high-ANL individuals, particularly those with concurrent moderate-to-moderately-severe SNHL, clinicians must aggressively deploy advanced digital features. This includes prescribing aggressive multi-channel digital noise reduction (DNR) algorithms, narrow adaptive directionality, and assistive listening technologies (such as remote microphones) to artificially optimize the SNR. Furthermore, identifying these profiles early allows for realistic pre-fitting counseling, establishing appropriate expectations, and introducing targeted auditory training regimens to ensure long-term device compliance.

Future longitudinal research should monitor whether targeted auditory training or extended acclimatization to premium deep-learning noise-isolation circuits can successfully lower an individual's baseline behavioral ANL over time.

Conclusion

This study demonstrates a clear, systematic relationship between the severity of sensorineural hearing loss and an individual's psychoacoustic capacity to tolerate background noise. As cochlear impairment progresses from mild to moderately severe, ANL thresholds escalate significantly ($r = 0.78$, $p < 0.001$). This finding indicates that pathophysiological distortions—such as loudness recruitment and the loss of frequency selectivity—fundamentally constrain an individual's subjective noise acceptance ceiling. Conversely, the remarkable consistency of ANL scores across Hindi and English linguistic stimuli confirms that background noise tolerance operates as a stable, centralized neurophysiological trait that remains independent of language-specific features or semantic familiarity.

Crucially, our regression modeling reveals that behavioral noise acceptance is a far stronger predictor of functional speech-in-noise performance ($R^2 = 0.38$) than the absolute Pure Tone Average ($R^2 = 0.24$). This underscores a vital clinical truth: successfully rehabilitating a patient with sensorineural hearing loss depends not only on what their ears can amplify, but on what their central auditory system is willing to accept. Individuals with low ANLs (≤ 7 dB) demonstrate a high intrinsic tolerance and an excellent probability of full-time device success. In contrast, hearing-impaired individuals with high ANLs (≥ 13 dB) face severe challenges in noise acceptance, experiencing a dramatic collapse in speech perception performance in competing backgrounds and a significantly higher risk of device abandonment.

In the contemporary era of evidence-based practice, clinical audiologists require rapid, objective, and standardized tools to guide intervention pathways, justify technology choices, and ensure an efficient use of clinical time and patient financial resources. While the ANL test has gained widespread popularity in developed countries as a simple yet powerful predictor of whether a client will accept the acoustic benefits of a hearing aid, it remains highly underutilized across both institutional setups and independent audiology clinics within India.

By delineating these correlative and predictive factors within a bilingual Indian cohort, this study familiarizes the regional audiological community with a robust, accessible tool. Incorporating routine ANL testing into pre-fitting batteries allows clinicians to move beyond simple "one-size-fits-all" target matches. Instead, it empowers them to accurately counsel patients, set realistic expectations, and proactively prescribe advanced digital noise reduction algorithms, narrow adaptive directionality, and assistive remote microphones for high-risk users—bridging the gap between what the ear can hear and what the individual is willing to tolerate.

Declarations

Ethical approval and consent to participate

All procedures performed in this study involving human participants were in accordance with the ethical standards of the Institutional Ethical Committee (IEC) of Command Hospital, Pune (Approval No: Research (ENT)/789(b)/IEC/CH(SC) dated 04 Dec 2023) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed written consent was obtained from all individual participants included in the study prior to the commencement of any diagnostic or behavioral evaluations.

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Author Contribution

Study concept and design: Lokanath Sahoo, Vishal Gaurav, Krushnendu Sundar SahooAcquisition of data: Lokanath Sahoo, Krushnendu Sundar Sahoo and Neha DeshmukhStatistical Analysis: Lokanath Sahoo, Krushnendu Sundar Sahoo and Vishal GauravAnalysis and interpretation of data: Lokanath Sahoo, Krushnendu Sundar Sahoo and Neha DeshmukhDrafting of the manuscript: Lokanath Sahoo, Vishal Gaurav, Krushnendu Sundar Sahoo and Neha Deshmukh Critical revision of the manuscript for important intellectual content: Lokanath Sahoo, Vishal Gaurav, Krushnendu Sundar Sahoo and Neha Deshmukh Study supervision: Lokanath Sahoo, Vishal Gaurav, Krushnendu Sundar Sahoo and Neha DeshmukhAll individuals listed as (co)-authors have met the authorship criteria, and nobody who qualifies for authorship is omitted from the list. The final manuscript was corrected and approved by all authors.

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